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About Reality of Voltage Harmonic Distortions with Frequencies Higher than 2 kHz in Power Industry Networks

ELECTROMAGNETIC COMPATIBILITY (EMC) AND POWER QUALITY

During high harmonics measurement in power networks and analyze of reasons of technology devices operation disturbance commonly it is attended to frequencies under 2.0-2.5 kHz (harmonics under 40-50 order). This situation is formed also because of actual European Norms, where harmonics with higher orders are shown insufficiently. For example, European Norm EN 50160 fixes maximum permissible levels of harmonics for public distribution systems under 25-th harmonic. Electric consumers can rely on these levels buying electrical energy. EN 50160 recommends calculate Total Harmonic Distortion (THD) value as geometrical sum of relative values of harmonics with order from 2 to 40:

$$THD_{n\leq 40} = \frac{\sqrt{\sum_{n=2}^{40} U_n^2}}{U_1}. \qquad (1)$$

This equation corresponds with others European Norms – EN 61000-2-4 for power industry networks and EN 61000-4-7 for harmonic measurement instrumentation.
European Norms EN 61000-2-2 (public low-voltage power supply systems) and EN 61000-2-12 (medium-voltage) fix limits under 50 harmonics. The value of THD is calculated as geometrical sum of harmonics with order from 2 to 50.
It is need to observe that harmonics in range 9 kHz – 30 MHz are studied by communication experts and CISPR fixes limits for high frequency voltages and currents. It was in plan that frequency range 2-9 kHz must be controlled of power electric specialists. But this plan wasn't realized probably due to minute observed extreme situations which need to be solved and due to absence of measurement devices.
Article authors have a digital oscillograph-analyzer «NEVA-IPE», which allows to realize spectrum analysis of voltages and currents till 200-th harmonic (till 10 kHz). Using of

oscillograph by measurements in operating power networks is allowed to find high frequency harmonics, which lead to disturbance of electronic devices.

For example, resonance increase of 59-th, 61-th, 71-th and 73-th harmonics were detected by voltage measurement on 10 kV bus-bar supplying power rolling mill in a metallurgical plant – see Fig.1.

Average of THD value by 3 phases calculated over all harmonics by equation

$$THD = \frac{\sqrt{U_{RMS}^2 - U_1^2}}{U_1} \qquad (2)$$

equals 20.6 % in this case, but THD value calculated according to EN 50160 by equation (1) equals 8.4 %. It is 2.5 times less than THD value according to (2). Impact of high harmonics more then 40 order equals

$$THD_{n>40} = \sqrt{THD^2 - THD_{n\le 40}^2} = 18.8\,\% \qquad (3)$$

Measurement results in power networks of others plants illustrating the presence of high harmonics with frequencies more than 2 kHz in currents and voltages are presented below.

Simultaneous values and spectrums of phase voltages in network 6 kV supplying 12-phase rectifiers of 4 MW frequency converters are shown on Fig.2. High frequency voltage fluctuations lead to electronic devices failure (personal computers, relays and power meters), disturb telephone lines.

Voltage spectrum calculated up to 10 kHz frequency (with sampling rate 20 kHz) evidently has harmonics with order more then 200. User could get $THD_{n\le 40}$=4.6% (see formula 1) in case of using a instrument with up to 40 harmonic measurement support only. But the real value of total harmonic distortion equals THD=11.2% (see formula 2), and the portion of n>40 harmonics equals $THD_{n>40}$=10.2% (see formula 3).

The main causes of high frequency harmonics appearance (Fig. 2), which is confirmed by simulations, are relative small value of insulation capacitive susceptance and presence of high frequency disturbances from controllable thyristor converter (Fig. 3). Converters have relatively small load (about 25 %) in this case. Commutating angles approach zero and big di/dt are observed. A sharp cuts of thyristors reverse current are observed 12 times a period, as a result harmonic distortion spectrum exceed 200 order. Inadmissible harmonic distortion are observed and by the nominal load in spite of commutating angles increase.

Voltage spectrums in 6 kV network supplying 5 MVA high frequency heating electric

furnaces (producer - ABB) via 12-phase rectifiers are shown on Fig. 4. Great changing of currents and voltages harmonic spectrums are observed by furnace load changing due to stage of regulation switching (there are 14 stages). Values of $THD_{n\leq 40}$ are not so great, but values of THD are inadmissible, especially by stages with a little load. The possibility of carrying out such complex analyze of harmonics appears due to oscillograph-analyzer «NEVA-IPE».

Some requests can be declare on the basis of foregoing.

1. Measuring instrument designers should extend the harmonic range.
2. Researchers should use oscillographs and special algorithms of measurement data processing by appearance of inadmissible high frequency distortions.
3. It is necessary to liven up research work by searching efficient ways of high frequency distortion supression. Specialists of Energosoyuz LTD work under solution of this complex problem.

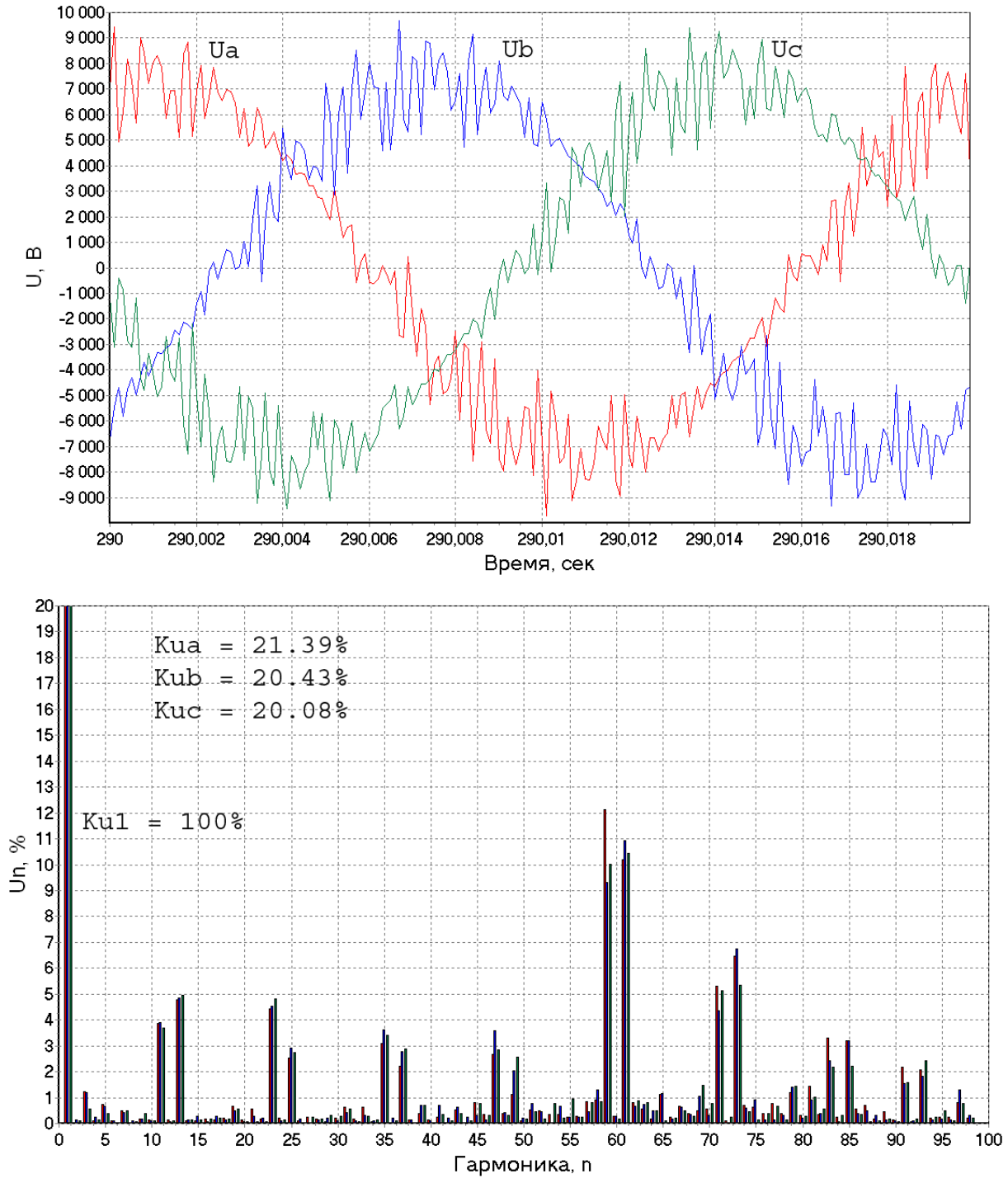

Fig.1. *Voltage and spectrum on 10 kV bus-bar supplying power rolling mill.*

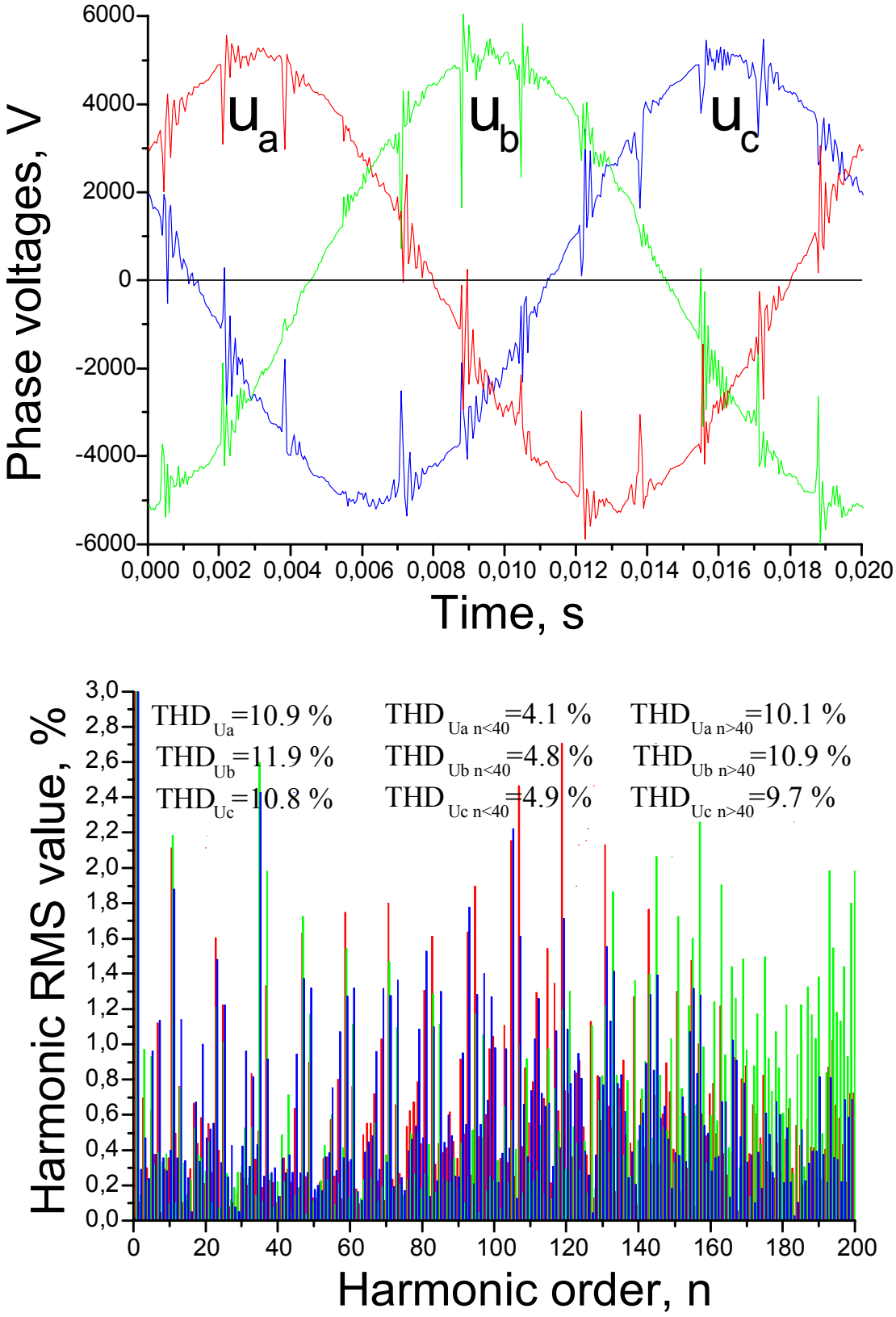

Fig.2. *Phase voltages and spectrums in network with frequency converters.*

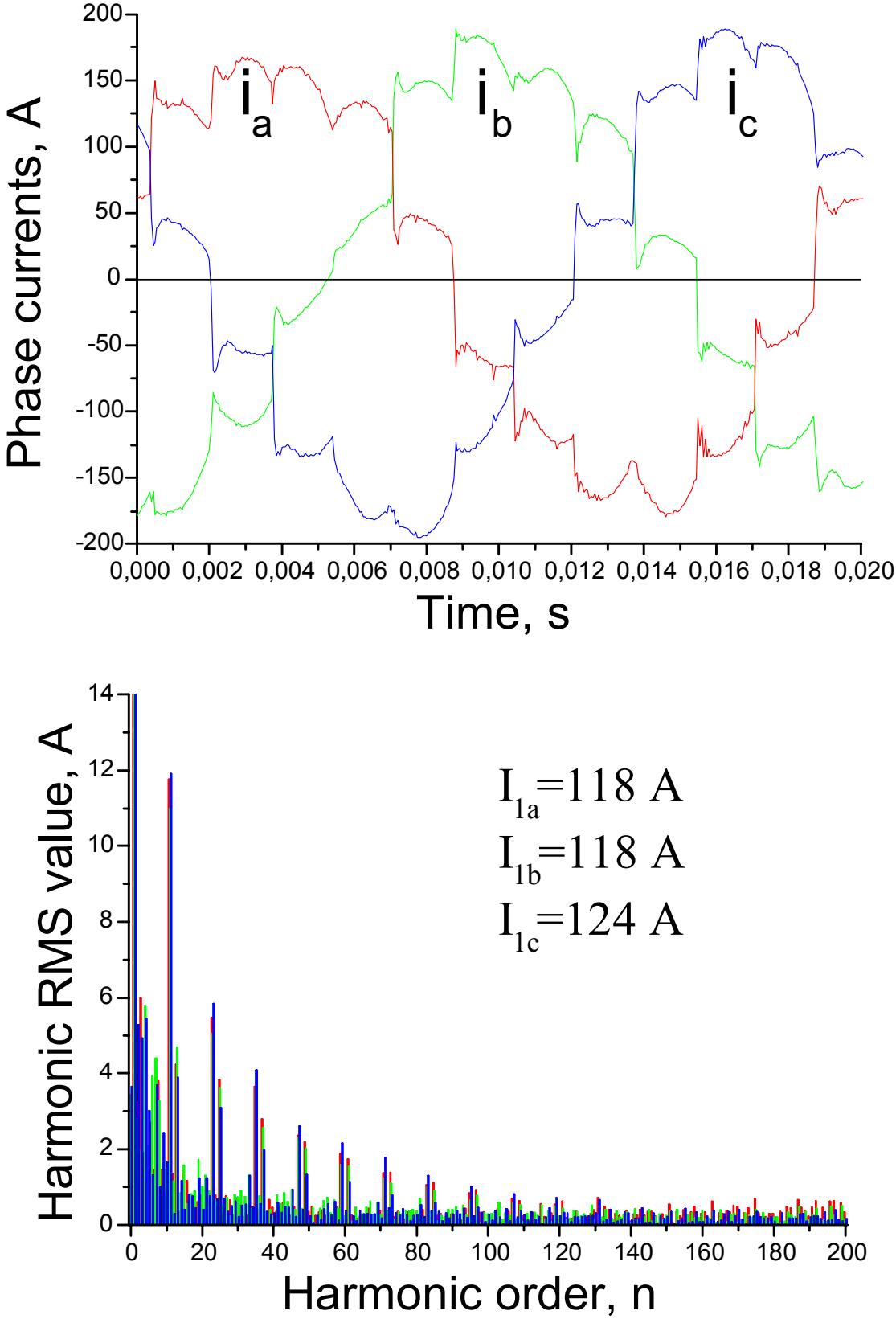

Fig.3. *Currents which lead to voltages distortion shown on Fig.2.*

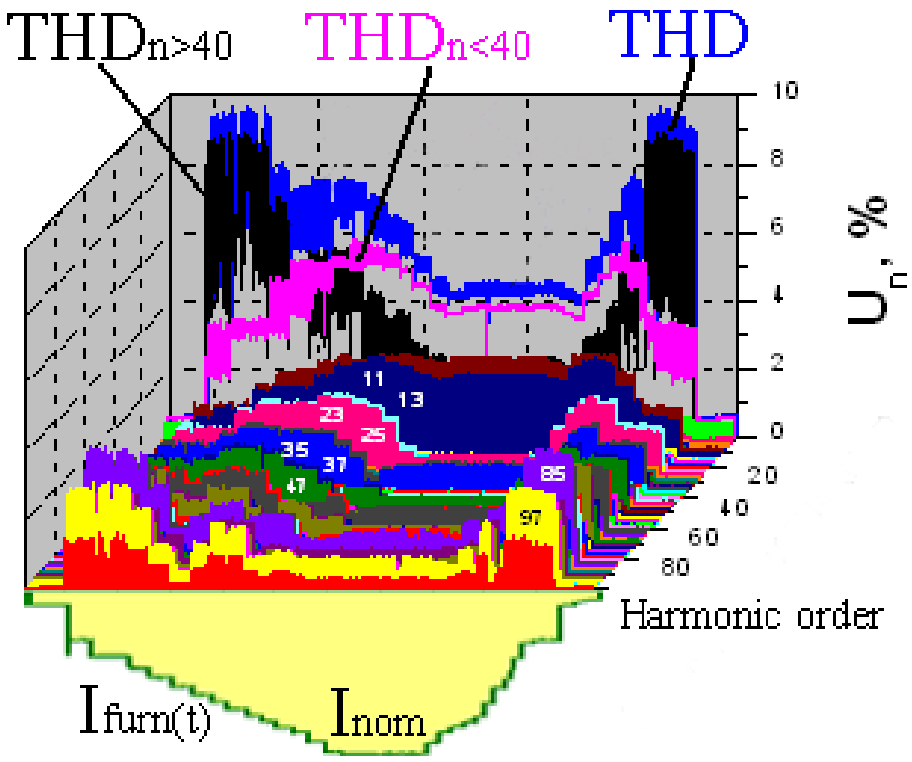

Fig.4. *Currents which lead to voltages distortion shown on Fig.2*

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